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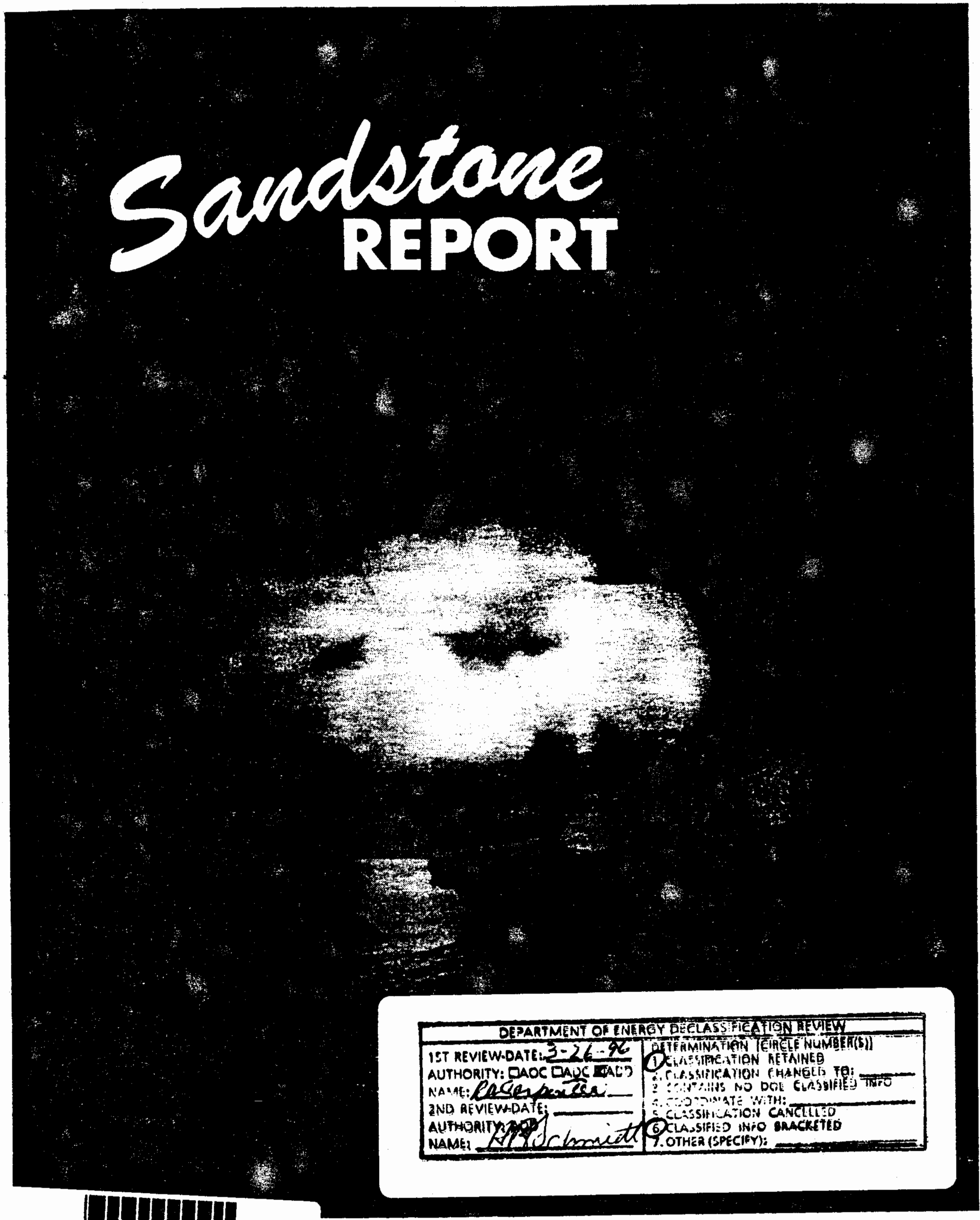
Sandstone REPORT



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EXTRACT from VOLUME III, pages 1 — 41 and pages 234 — 285 only

SCIENTIFIC DIRECTOR'S REPORT OF ATOMIC WEAPON TESTS AT ENIWETOK, 1948

SANDSTONE HANDBOOK OF NUCLEAR EXPLOSIONS (U)

Editor, Frederick Reines

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1.2 SUMMARY OF CONTENTS

Chapter 1

This chapter describes the purpose and contents of the Handbook and gives in Table 1.1 a timetable of events which take place in a nuclear explosion, in Table 1.2 a summary of values for certain important quantities such as predicted energy releases, and a statement of the purpose of Operation Sandstone.

Chapter 2

After a description of the various models, there is a discussion of the pre-nuclear stage during which detonators are fired, active material is assembled into a supercritical configuration, and neutrons are introduced into the system by the initiator. The time from detonation to initiation, called the transit time, is listed for various models. The experiment designed to measure transit time is described and the use of the results of this experiment is discussed.

Chapter 3

Various stages in the development of nuclear energy as the bomb prepares to expand are described. Theoretical curves for the multiplication rate are presented. The value of a measurement of this rate for diagnosing the performance of the bomb is discussed. The probability of predetonation is

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considered in some detail and curves are given for the probability of an explosion with less than a certain yield. Comments are made on the hydrodynamic phases of nuclear energy generation with the view of explaining estimates of efficiency and energy yield of an explosion. An analysis is made of two proposed experiments for measuring the initial multiplication rate.

Chapter 4

Neutron effects in a nuclear explosion are described. Estimates are given for the expected intensities of neutrons of energy $\geqslant 3$ Mev. Neutron threshold-detector experiments which will be done are described.

Chapter 5

The status of theory and experiment on gamma radiation is described briefly. A detailed description is given of the gamma radiation experiments planned for the 1948 tests.

Chapter 6

The development of the shock in air caused by a nuclear explosion is described. Curves are presented for the variation of pressure with distance, pressure with time at fixed distances, impulse versus distance, arrival time of shock versus distance, for different nuclear energy releases. A detailed timetable is given for the progress of the blast wave as well as for the motion of the cloud. A scheme for

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determining energy release from ball of fire observations is discussed and calibration curves are included.

Chapter 7

Efficiency is defined as the number of fissions per active atom (i.e., Pu^{239} and/or U^{235}) originally in the bomb core. This chapter elaborates principles of the radiochemical procedure which is used to determine this quantity. [redacted] A summary of the results of previous radiochemical determinations is given.

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Chapter 8

In this chapter, a selection of rough schemes to determine energy yield is presented. Such methods as the observation of the maximum radius of the ball of fire at which the ball is almost uniformly bright and the more conventional use of a microbarograph record are discussed and curves are provided for field use.

Chapter 9

Attention is given to the problem of interpreting the results of experiments. Criteria are presented for the judgment of the success of a test. Various possibilities are analyzed and alternative interpretations are presented for the possible results. Particular attention is paid to the coordinated interpretation of key experiments which measure energy release, initial multiplication rate, and transit time.

Appendices

In the appendices, a collection of useful data is provided. Appendix C on the expected post-shot ground activity is felt to be of particular interest. The question of information which might be obtained from the test site after the test has been discussed in Appendix D.

1.3 PURPOSE OF TESTS

[redacted] b3

Since it is possible to learn something about the mechanism of a nuclear explosion, other experiments than those designed to measure total energy release will be done.

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Table 1.1

Timetable of Events for 20-Kiloton Explosion

(Trinity Type Bomb)

t(sec)	Event
0	Detonators Pulsed
0.4	Ball of fire Max. Radius 400 yds.
0.4	Shock reaches 500 yds.
1.29	Shock reaches 1000 yds.
6.44	Shock reaches 3000 yds.
12	Shock reaches 5100 yds.
12	Ball of fire reaches 2000 ft.
70	Ball of fire reaches 12000 ft.
258	Ball of fire reaches 28000 ft.
598	Ball of fire reaches 40000 ft.

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Chapter 2

THE IMPLOSION

E. Zadina and F. Reines

2.1 INTRODUCTION

During the course of these tests three types of atomic bombs will be detonated. In expected order of detonation they are:

1. [redacted]
2.
3.

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Order of Firing [redacted]

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Criteria for performance and order of detonation appear in Chapter 9.

[redacted]

The term "composite" is applied to those bombs in which the active material consists of both Pu^{239} and U^{235}. [redacted]

Bomb Types

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[redacted] Features of the bombs to be tested are given in Figures 2.1, 2.2, and 2.3 and Table 2.1.

2.2 DETONATORS

[redacted]

Transit Time and Simultaneity

[redacted]

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(1) Communicated by L. Seely.

[redacted] b3

Implosion Time-Table

Adjacent to these are listed, where measurements exist, the corresponding times obtained experimentally by the pin method. Zero time in all cases is the moment at which the voltage pulse arrives at the detonator.

The chief criterion by which the success of an implosion is judged is the degree of compression achieved in the core of active material. The reason for this is that the critical mass is roughly inversely proportional to the square of the density. Thus if the density is doubled, the critical mass will be smaller by about a factor of 4 [redacted]

Compressions

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[redacted]

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CHAPTER 7

MEASUREMENT OF BOMB EFFICIENCIES BY RADIOCHEMICAL METHODS

R. W. Spence

7.1 DEFINITION OF EFFICIENCY

At Trinity and at Bikini the bomb efficiency, E, was defined as follows:

$$E = \frac{\text{Total number of fissions}}{\text{Total number of } Pu^{239} \text{ atoms originally in bomb core}} \qquad (7.1)$$

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The corresponding definition for a composite bomb, one containing both Pu^{239} and separated U^{235}, would be:

$$E = \frac{\text{Total number of fissions}}{\text{Number of } Pu^{239} \text{ atoms originally in bomb core} + \text{number of } U^{235} \text{ atoms originally in bomb core}} \qquad (7.2)$$

This is again a figure which one would

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formula plotted in Figure 8.5.

$$W = C\left[1+\left(\frac{R}{200}\right)^2\right]^{3/2} \qquad (8.3)$$

where $C = 30$ when R is the radius in feet for pulverizing macadam, and

$C = 1$ when R is the radius out to which dishing occurred.

This method is perhaps good to a factor of two.

8.6 RADIUS OF FIRED CORAL

In the region of strong shocks, $T \sim W/T^3$ where T is the temperature. Coral is essentially $CaCO_3$ with a temperature of decomposition of $\sim 700°C$; Trinity soil is essentially SiO_2 and fuses at $\sim 1500°C$. Inserting these numbers into the above relationship we find that, scaling from the Trinity fused area (Figure 8.6).

$$W = 1.4 \times 10^{-5} R^3;\ W \text{ in kilotons, } R \text{ in feet.} \qquad (8.4)$$

This method is probably only good to a factor of two because of the irregularity of the fused area, the differences in the

CHAPTER 9

REASONING FROM EXPERIMENTAL RESULTS

F. Reines and H. Mayer

9.1 INTRODUCTION

To implement the purpose of the Eniwetok tests, the most important set of experiments are those that measure the efficiency of the nuclear explosion. These include, in order of demonstrated reliability, the radiochemical measurement of the number of fissions, the ball of fire observations, and the blast measurements. Of secondary importance are the transit time and multiplication rate, alpha, measurements which are, however, particularly useful in checking our ideas of the processes which occur in a nuclear explosion. A host of additional experiments will be performed, providing information of more general scientific interest, but at present they can only be crudely related to the internal workings of an atomic bomb. This chapter, therefore, will concentrate on the coordinated interpretation of

Efficiency
α
Transit Time

the efficiency, transit time, and alpha measurements.

9.2 ABSOLUTE EFFICIENCIES

A good measure of the performance of a particular design of atomic bomb is its efficiency, i.e., the number of fissions per valuable (separated U^{235} or Pu^{239}) fissile atom present. [redacted]

DOE b3

However, there exist other goals than high efficiency alone: [redacted]

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$$\text{F.M.} = \frac{W^{2/3}}{8M_{Pu}239 + 6M_U235} \qquad (9.1)$$

Here $M_{Pu}239$ is the mass of Pu^{239}, $M_U{}^{235}$ is mass of separated U^{235} in the bomb and we assume a relative economic v value of the two materials given by the weighting numbers in (9.1).(1) The estimated figures of merit for the various models relative to Trinity are as follows:

Table 9.1

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The observed figure of merit, corrected perhaps for current or estimated future costs of Pu^{239} and U^{235}, is the suggested criterion

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[redacted]

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9.5 COMMENTS

Confirmation of Efficiency Formula

The primary objective of the Eniwetok tests (cf. Chap. 1) can be realized through a study of the previously mentioned experiments. In the fortunate circumstance that the efficiency of the bomb is that predicted, we will have valuable experimental verification of the semi-empirical Bethe-Feynman efficiency formula over a wide range of bomb models. We may then use this formula with greater confidence in future predictions for bombs of similar design. The extent to which the formula applies to different models may also be learned from these tests.

Probabilities

From the test of a limited number of bombs, and particularly only one bomb of a given type, we can never hope to learn about questions involving probabilities, for example, predetonation. The use of large numbers of bombs in warfare may well change our attitude towards the conclusions of these

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tests because such probability considerations will then apply.

Weapons as Research Tool

In addition to the primary objective, information of more general scientific interest may be furnished by the variety of experiments to be performed, e.g., gamma-x-ray attenuation in air. It should be recognized that nuclear explosion provides conditions found nowhere else in the universe — for example, temperatures [redacted] enormous neutron and gamma fluxes, quantities of radioactive material in fantastic amounts, radiation pressures exceeding those found in the sun — and should be exploited, wherever possible as a research tool.

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